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14. ABSTRACT
This work is sponsored by ONR as part of a joint research project with the NATO SACLANT Center Sound, Oceanography and Living MArine Resources (SOLMAR) project in La Spezia, Italy. Within this SACLANTCEN project multiple interdisciplinary sea trials (Sirena campaigns) have been successfully conducted in the northwestern Mediterranean Sea since 1999. Six sea trials have been conducted in the northwestern Mediterranean Sea from 1999 to 2003 during the late spring/summer season. The main goal of the project was correlating relevant environmental and biological parameters with concurrent marine mammal sightings. Among the different species inhabiting the area, Cuvier's beaked whale, Ziphius cavirostris, which is the only beaked whale commonly found in the Mediterranean Sea, was chosen as the focal species. Since the Genoa Canyon was a known habitat for Cuvier's Beaked Whales (Fig.1), in 2002 a dedicated single ship cruise was conducted in the canyon region collecting oceanographic (21 CTD stations), visual and acoustic data in an area of about 10,600 km2. On-effort sightings were made during transect between the CTD stations

15. SUBJECT TERMS
Cuvier's beaked whale, Ziphius cavirostris, Mediterranean Sea, habitat characterization, CTD, acoustics, visual observations

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FINAL REPORT

Grant number: N00014-04-1-0773

PRINCIPAL INVESTIGATOR: Peter L. Tyack & Arianna Azzellino

GRANT TITLE: Statistical Analyses of Marine Mammal Occurrence, Habitat Associations and Interactions with Ocean Dynamic Features

AWARD PERIOD: 15 August 2004 - 30 March 2006

OBJECTIVE:
This work is part of a joint research project with the NATO SACLANT Center Sound, Oceanography and Living MArine Resources (SOLMAR) project in La Spezia, Italy.

Within this SACLANTCEN project multiple interdisciplinary sea trials (Sirena campaigns) have been successfully conducted in the northwestern Mediterranean Sea since 1999. Six sea trials have been conducted in the northwestern Mediterranean Sea from 1999 to 2003 during the late spring/summer season. The main goal of the project was correlating relevant environmental and biological parameters with concurrent marine mammal sightings. Among the different species inhabiting the area, Cuvier's beaked whale, Ziphius cavirostris, which is the only beaked whale commonly found in the Mediterranean Sea, was chosen as the focal species. Since the Genoa Canyon was a known habitat for Cuvier's Beaked Whales (Fig.1), in 2002 a dedicated single ship cruise was conducted in the canyon region collecting oceanographic (21 CTD stations), visual and acoustic data in an area of about 10,600 km2. On-effort sightings were made during transect between the CTD stations and while on station. 17 sightings of Cuvier's Beaked Whales were made. Therefore during these cruises, visual sightings were made along with concurrent oceanographic measurements in the canyon region.

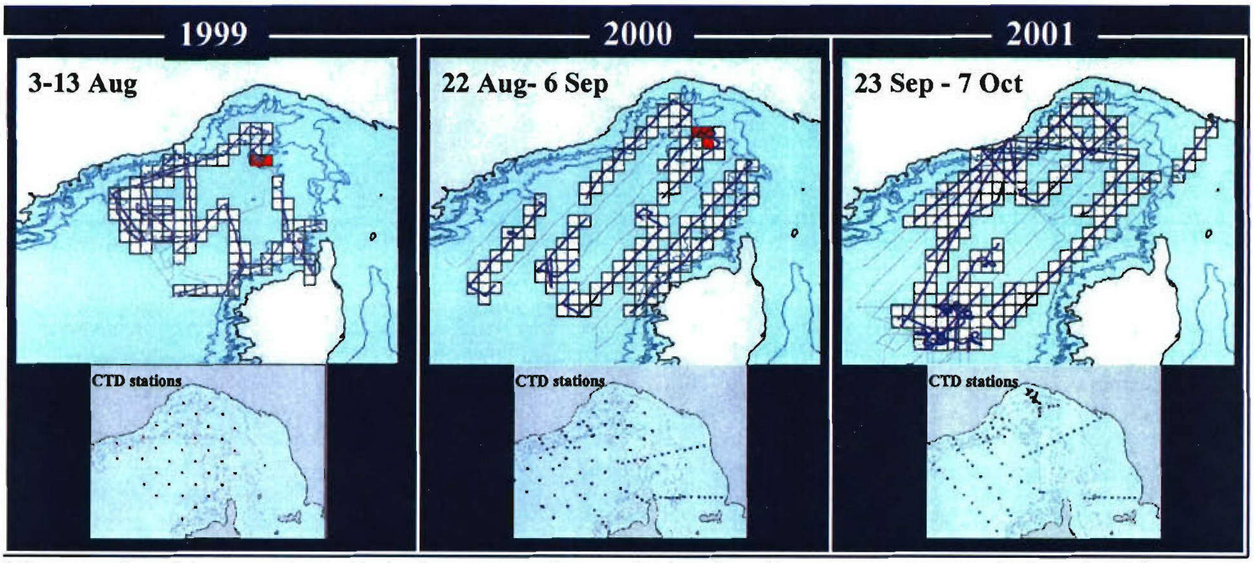


Figure 1: Sirena Sea Trials: yearly multi-platform at-sea trials in the Ligurian Sea, (~ 31,000 km^2, shown as blue tracks). Presence (cells with sightings of Cuvier's beaked whale, drawn in red) are shown together with Absence cell (cells with effort and no sighting of Cuvier's beaked whale, drawn in gray).

1.1. Canyon peculiarity within the Ligurian Sea basin

The Ligurian Sea is a deep semi-enclosed basin in the northwest Mediterranean Sea, bordered by the coastlines of France and Italy. Water depths in the Ligurian Sea extend to greater than 2000m. The general circulation of the Ligurian basin is the combined result of two major branches of water, the Ligurian Current and the West Corsican Current. During part of the year, there is also the influence of water flowing from the Tyrrhenian Sea along the east side of Corsica. When these water masses join together north of Corsica, they create a cyclonic pattern that moves in a southwest direction following the continental shelf, flowing between 50 and 250m. A frontal region is commonly found at the limit of the cold core of the cyclonic Ligurian Sea circulation and the warm waters moving parallel to it.

The upwelling of cold, nutrient rich water in the basin center is generally visible on the Sea Surface Temperature (SST) images by a cooler area on all images. SEAWifs images (Chlorophyll-a) show the same region of upwelling to be an area of high productivity (Fig.2). The area is rich in marine mammals and was designated at International Cetacean Sanctuary in 1999.

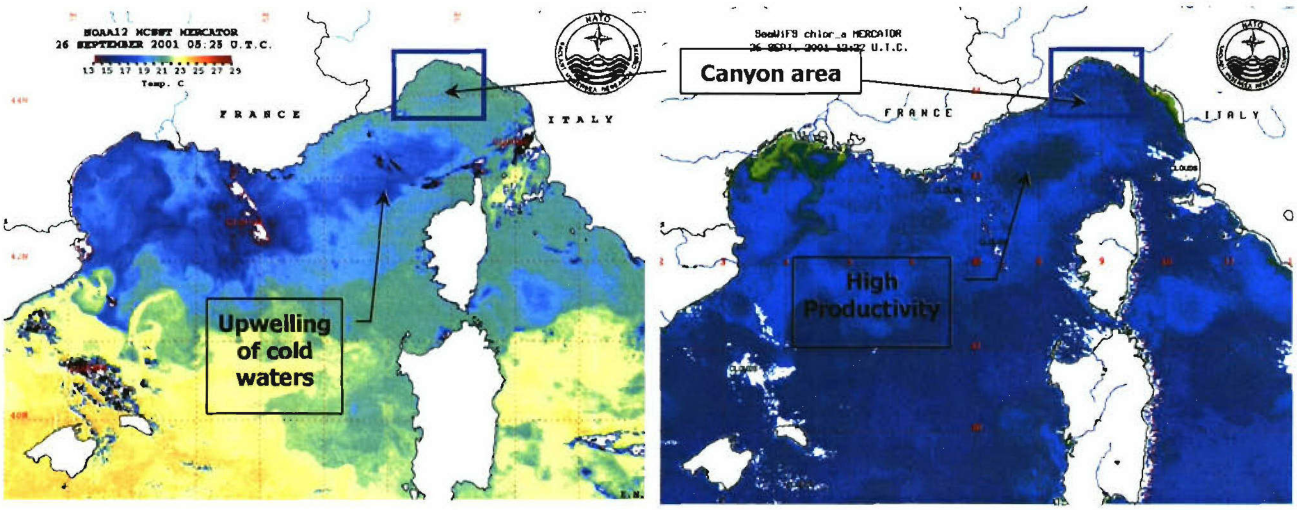


Figure 2: Ligurian Sea Basin and Canyon area. Both the cold and nutrient-rich upwelling in the center of the basin and the canyon area are shown.

The Genoa canyon region is in the far northeastern portion of the Ligurian sea, highlighted by the boxes in Fig.2.

1.2. Previous results

The canyon area was subdivided into a grid of 486 cells of about 3 nm sq. For every cell the visual sighting effort was evaluated and the environmental characteristics were analysed. Factor analysis was applied to the data set to simplify both the oceanographic and the biological parameters. 6-8 Factors were able to explain up to 91% of the original oceanographic and biological variance. These factors were used as environmental predictors and calculated for every cell by means of a spatial interpolator (IWD: Inverse Weighted Distance interpolator). This analysis characterized the entire water column (i.e. oxygen and density gradients, autotrophic components, elemental and biochemical composition of particulates) and the general patterns of the Euphotic zone (i.e. maximum fluorescence and dissolved oxygen, chl-a and

phaeopigments).Finally beaked whale presence/absence data were analyzed by using a Stepwise Logistic Regression method. The resulting logistic model had a good fit (Nagelkerke R^2 >0.80) and the resulting model was able to predict a high percentage (94 %) of presence/absence cells. Furthermore the model outlined a lack of correlation with most of the near surface oceanographic and biological factors suggesting that beaked whale presence has a stronger correlation with environmental conditions related to the mesopelagic zone.

1.3. Scope of this work.

The main idea of this further step of analysis was to investigate more deeply the oceanographic peculiarity of the canyon area by using the data collected in 2003 during two additional sea trials (Ziphius campaigns) which have been focused specifically on the canyon area. The maps in Fig.3 show the CTD measurement scheme of the two Ziphius campaigns that were respectively conducted in a late-spring and early-fall period.

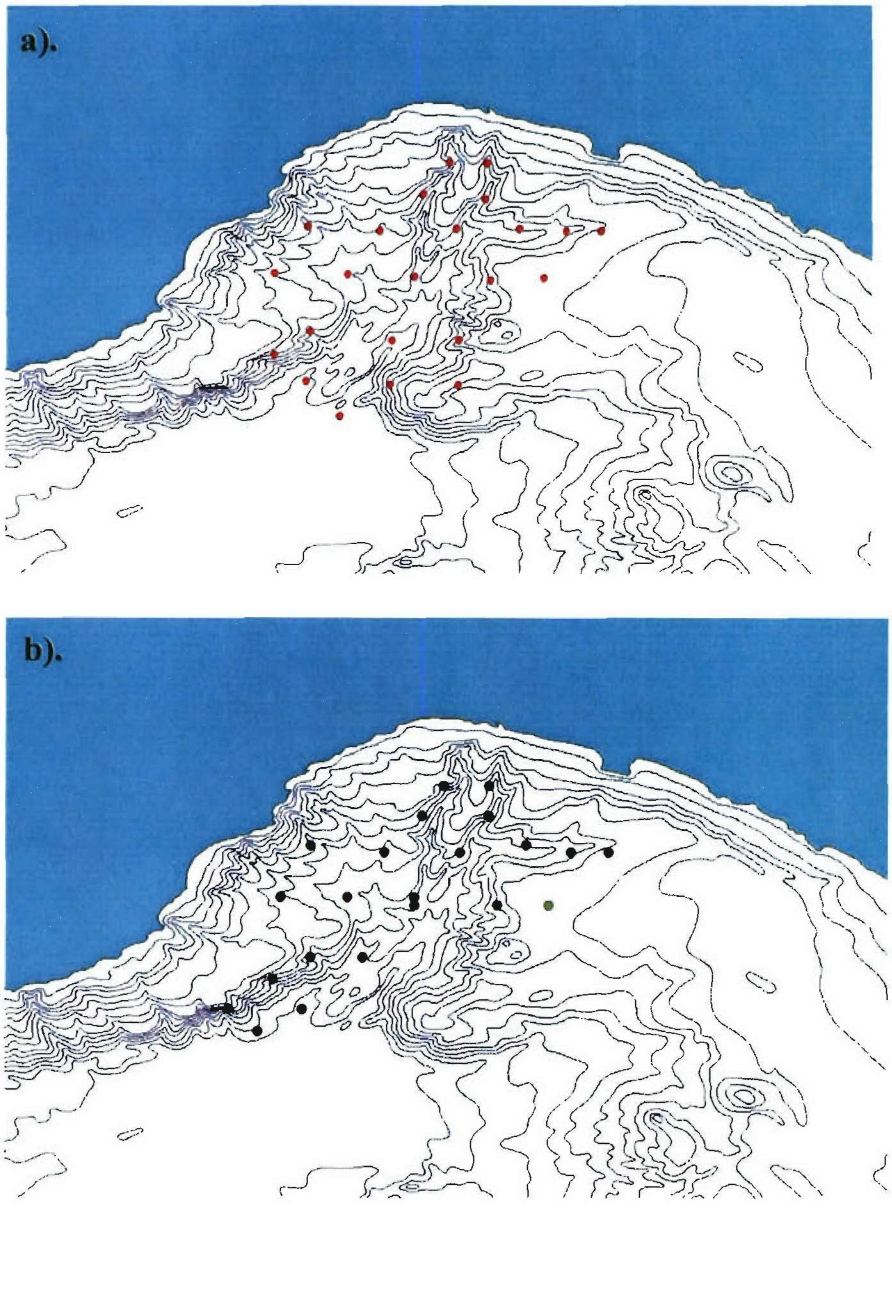


Figure 3: CTD measurement stations in the canyon area of the 2004 Ziphius campaigns: a). 29 Apr - 8 May 03 campaign; b). 4 Sep - 11 Sep 03 campaign.

By using as reference the findings of the 2002 campaign and the results of the predictive model developed with the 2002 sighting and environmental data, this new step of analysis was aimed at assessing whether the environmental "fingerprint" of the cells that for the 2002 data were found of interest for beaked whales is maintained also in periods other than summer.

APPROACH:

1.4. Principal Component Analysis

All the techniques aimed to replace the original and usually large set of variables by a much smaller set of derived variables which still retain most of the relevant information are generally called ordination techniques. Ordination tries to approximate the complex pattern of a full data set in few dimensions. If the reduction in dimensionality is sufficient, the results can be presented visually by plotting graphs of the new variables against each other. Thus the ordination allows one to visualize the complexity of a large data matrix by outlining the relationships between the variables and by reducing the redundancy of the information contained. Principal Component Analysis (PCA) was the first ordination technique to be developed and it is still the most used. In PCA linear combinations of the original variables are created that embody as much as possible of the variance in the data.

$$F_1 = w_{11}X_1 + w_{12}X_2 + \dots + w_{1k}X_k$$
$$F_2 = w_{21}X_1 + w_{22}X_2 + \dots + w_{2k}X_k$$

where:

F_1 are the principal components or factors

X_i are the original correlated variables

w_{ij} are factor scores chosen to satisfy the requirements of maximising the variance (eigenvalue) explained by every relationship, and of having orthogonal factors resulting from the extraction (i.e. uncorrelated).

The first new variable, or principal component axis, is chosen to account for the maximum amount of variance possible in a single variable and the subsequent principal component axes are chosen to explain as much as possible of the remaining variance while being uncorrelated with previously derived axes. New components can be calculated until all of the original variance is accounted for and the maximum number of possible components is the same as the number of the original variables. The complete set of principal components therefore forms a set of new variables which embody successively smaller proportions of the original total variability. The Scree plot in Fig.4 shows the standardised amount of variance (eigenvalue) explained by each component. The rationale behind PCA is that if the first few components account for most of the variance, then hopefully they also represent most of the important information in the data and the remainder can be ignored, thus reducing the number of variables to be analysed.

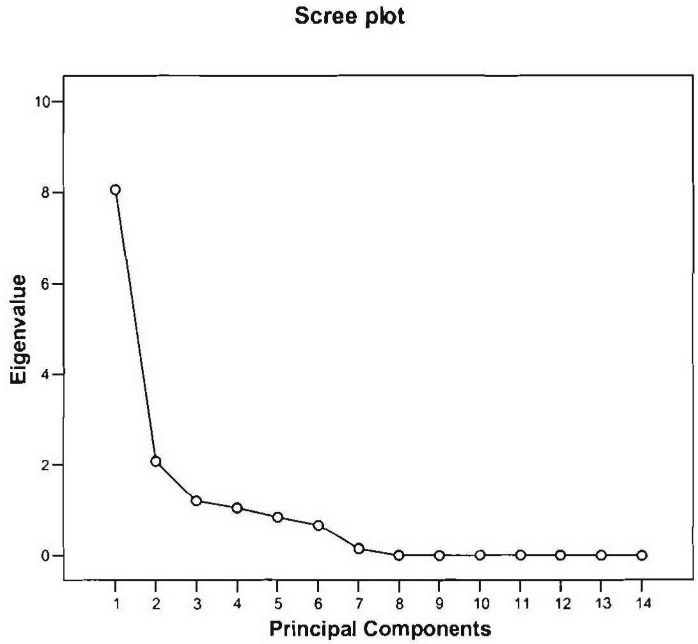


Figure 4: The Scree plot shows the standardised amount of variance (eigenvalue) explained by each component. As it can be seen from the graph, the principal components that are extracted subsequently after the first component embody successively smaller proportions of the original total variability.

Principal components are usually derived from either raw data (via the covariance matrix) or from standardised data (via the correlation matrix). Using standardised data can be thought of as giving all the variables equal importance regardless of their scale of measurements. PCA will perform effectively only if the original variables are correlated. Obviously the new set of variables (the principal components) can used in subsequent forms of analysis in place of the original variables. By looking at the factor loadings matrix (i.e. the list of the correlation coefficients of the original variables with the extracted components, Table 1) it is possible to identify the most meaningful parameters within each component. Parameters that lie on the same component reasonably share the the same type of information. Generally the number of components that is retained is chosen on the basis of the "eigenvalue higher than 1" criterion (i.e. the analyst will retain only the components that explain more than the variance of one of the original variables). In the example of Fig.4, four components should be maintained on the basis of the "eigenvalue higher than 1" criterion.

1.5. Factor Analysis

Factor analysis is similar to principal components analysis in that it is a technique for examining the interrelationships among a set of variables. However in principal components analysis the major objective is to select a number of components that explained as much of the total variance as possible. On the other hand, the factors obtained in factor analysis are selected mainly to explain the interrelationships among the original variables. The major emphasis in factor analysis is placed on obtaining easily understandable factors that convey the essential information contained in the original set of variables. Very often PCA

constitutes the first step of the factor extractions. However factor analysis enables to further reduce the contribution of the less significant parameters within each principal component, by extracting a new set of varifactors through rotating the axis defined by PCA. The Varimax rotation criterion, which is the most commonly used, allows to rotate the principal component axes so that they go through clusters or subgroups of the points representing the response variables even though maintaining their orthogonality (i.e. being uncorrelated) to each other. After a Varimax rotation the factor loadings corresponding to the rotated axes differ from the unrotated factor loadings (PCA factor loadings) since the all variables that in the unrotated solution had a high loading maintain such a high or show an even higher loading whereas the rotated loading of all the variable that had a medium or low loading in the unrotated PCA solution significantly decreases (see Table 2).

Table 1: Factor loadings matrix. Each loading represents the correlation between the item (i.e. the original variables) and the component.

Factor Loadings

	Components			
	1	2	3	4
prDM	.852	.123	.434	.262
t090C	-.328	.914	-.218	-.054
cond	.380	.906	-.124	-.021
sbeox0V	-.984	.033	.083	.075
flC	-.573	-.149	.180	.160
seaTurbMtr	-.029	.062	.459	-.722
xmiss	.288	-.146	-.407	.421
sbeoxMLL	-.942	-.001	.246	.169
sbeoxMgL	-.942	-.001	.246	.169
sbeox0P	-.946	.071	.225	.163
sal	.945	-.083	-.119	-.124
svCM	.821	.347	.380	.246
Density	.862	-.469	.035	-.052
Depth	.852	.123	.433	.262

By comparing Table 1 with Table 2, it is quite evident that whereas some of the PCA loadings appear decreased some others are increased. For example the variable prDM (pressure) that had a high loading on the first principal component and medium loading on the third principal component, after the rotation has a high loading only on the third component. That obviously helps in interpreting the factors since if the third principal component had a lot a medium loading variables and was difficult to name, the second rotated factor which has received a very high load for prDM can be easily called the pressure/depth component.

In factor analysis, as for PCA, the number of factors to be retained can be chosen on the basis of the "eigenvalue higher than 1" criterion (i.e. all the factors that explain less than the variance of one of the original variables are discarded). Table 3 gives eigenvalues, variance explained, and cumulative variance explained for the factor solution. For the initial solution (i.e. principal component analysis), there are as many components or factors as there are variables. The "Total" column gives the amount of variance in the observed variables accounted for by

each component or factor. The "% of Variance" column gives the percent of variance accounted for by each specific factor or component, relative to the total variance in all the variables. The "Cumulative %" column gives the percent of variance accounted for by all factors or components up to and including the current one.

Table 2: Rotated factor loadings matrix. Each loading represents the correlation between the item (i.e. the original variables) and the rotated factors.

Rotated factor loadings

	Factors			
	1	2	3	4
prDM	-.409	.909	-.047	-.035
t090C	.223	-.151	.959	.051
cond	-.306	.321	.885	.007
sbeox0V	.872	-.457	.065	.088
flC	.596	-.164	-.162	.015
seaTurbMtr	-.073	-.009	-.024	.855
xmiss	-.244	.040	-.073	-.617
sbeoxMLL	.939	-.291	-.014	.098
sbeoxMgL	.939	-.291	-.014	.098
sbeox0P	.937	-.293	.061	.099
sal	-.879	.378	-.101	-.071
svCM	-.396	.898	.186	-.026
Density	-.746	.380	-.509	-.074
Depth	-.410	.909	-.047	-.035

Extraction method: Principal Component Analysis
Rotation criterion: Varimax with Kaiser normalisation.

Table 3: Initial Eigenvalues, variance explained, and cumulative variance explained for the principal component and the factor analysis solution. As it can be seen the cumulative percent of variance accounted for by the 4 retained factors is the same for both the rotated and the unrotated (extraction sum of squares loadings) solution. However the overall amount of variance is differently distributed among the components in the rotated solution.

Explained Total Variance

	Initial Eigenvalues			Extraction Sum of Squares loadings			Rotation Sum of Squares loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.063	57.594	57.594	8.063	57.594	57.594	5.789	41.347	41.347
2	2.088	14.912	72.506	2.088	14.912	72.506	3.365	24.038	65.385
3	1.186	8.471	80.977	1.186	8.471	80.977	2.051	14.650	80.035
4	1.033	7.378	88.355	1.033	7.378	88.355	1.165	8.320	88.355
5	.836	5.975	94.330						
6	.654	4.671	99.000						
7	140	.997	99.997						
8	.000	.002	99.999						
9	9.164E-05	.001	100.000						
10	1.673E-05	.000	100.000						
11	7.594E-06	5.424E-05	100.000						
12	2.920E-07	2.086E-06	100.000						
13	4.431E-08	3.165E-07	100.000						
14	1.596E-11	1.140E-10	100.000						

Cluster Analysis

The purpose of cluster analysis is to identify groups of clusters of similar data within a data set. There is a relevant variety of methods for clustering individual units. These methods can be broadly divided into a hierarchical or non-hierarchical techniques, where hierarchical means that individual units are put into a hierarchy of groups with a tree-like branching structure represented by a dendrogram (see Fig.5).

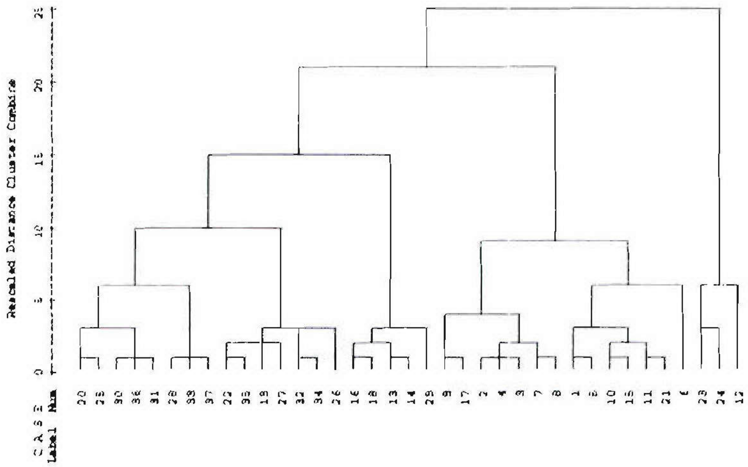


Figure 5: The Dendrogram shows the hierarchy of the units' similarity. Individual units 20 and 25 are more similar to each other than to the units 30, 36 and 31 however these five units more similar together than the group composed by the units 28, 33 and 37 and so on.

Hierarchical techniques are themselves subdivided into agglomerative and divisive methods. Agglomerative techniques start with each unit as a separate cluster and gradually combine individual units and groups of units until a single group or a small number of groups remain. This can be considered a bottom-up approach. The alternative divisive hierarchical approach might be considered a top-down approach as, starting with all the units in the same group, the set of units is gradually and successively split into more and more clusters. Divisive hierarchical techniques are little used in practice, largely because of the computational resources needed to form an optimal division of a large group of units. The most frequently used non-hierarchical method of clustering is K-means clustering. Here the number of groups is chosen beforehand and, starting from an "initial seed unit" in each group, the remaining units are allocated to the group to which they are most similar, where dissimilarity is measured by squared Euclidean distance of the unit from the group's centroid or mean. After all units have been allocated they may be swapped between groups in an attempt to improve the separation between the groups as obtained by minimizing some criteria such as the sum of within-group squared distances. Agglomerative hierarchical techniques are the most commonly used cluster methods. All agglomerative hierarchical methods start with a matrix giving the similarity or distance between each pair of units. This can be calculated in a number of ways; the most appropriate should be dictated by the form of data. At any stage in an agglomerative clustering approach, the next two units/groups joined are those with the least "inter-group distance" (or the highest "inter-group similarity"). The definition of inter-group, as opposed to inter-unit, distance depends on the linkage method used.

Linkage methods that are commonly used are (Fig.6):

a) Single Linkage (nearest neighbour): distance between two groups is the shortest distance between any point in the first group and any point in the second group;
b) Complete Linkage (furthest neighbour): distance between two groups is the furthest distance between any point in the first group and any point in the second group;
c) Group average: distance between two groups is the average of all possible distances between any point in the first group and any point in the second group;
d) Median: distance between two groups is the median of all possible distances between any point in the first group and any point in the second group;
e) Centroid: distance between two groups is the distance between the means of the two groups;
f) Ward's method (minimum variance): joins the two groups for which the increase in overall within cluster variance is least.

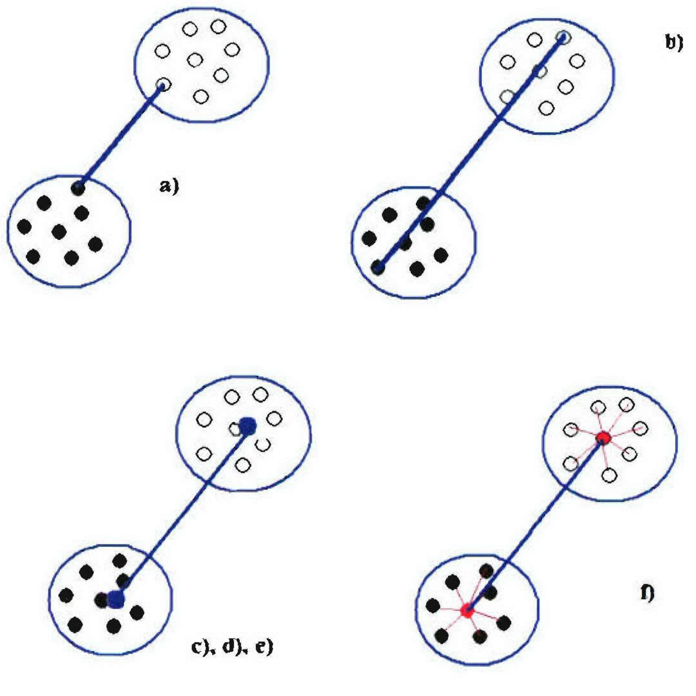


Figure 6: Commonly used linkage methods. a) single linkage; b) complete linkage; c)d)e) average, median, centroid linkage; f) Ward's method.

The combined choice of a distance measure and of a linkage method results in a remarkable set of possible options of which there is no universally agreed optimum however Euclidean distance and Ward's method is probably the combination preferred by statisticians.

<u>ACCOMPLISHMENTS:</u>

1.6. Ziphius A campaign (29 Apr - 8 May 2003)

Factor Analysis
As first step for the analysis a factor analysis was applied to the Ziphius A campaign data.

Factor Analysis was based on standardized data via a previous correlation analysis obtained by pooling all the CTD data together (see Table 4). The VARIMAX rotation allowed rotation of the principal component axes. These resulting factors maintained their orthogonality (i.e. being uncorrelated) to each other. Factor Analysis results are shown in Table 5. Four factors were retained on the basis of the "eigenvalue higher than 1" criterion.

Table 5: Initial Eigenvalues, variance explained, and cumulative variance explained for the principal component and the factor analysis solution. The factors were interpreted on the basis of the factor loadings (Table 6).

Explained Total Variance

	Initial Eigenvalues			Extraction Sum of Square loadings			Rotation Sum of Square loadings		
Component	Total	% of Variance	% Cumulatve	Total	% of Variance	% Cumulatve	Total	% of Variance	% Cumulatve
1	8.063	57.594	57.594	8.063	57.594	57.594	5.789	41.347	41.347
2	2.088	14.912	72.506	2.088	14.912	72.506	3.365	24.038	65.385
3	1.186	8.471	80.977	1.186	8.471	80.977	2.051	14.650	80.035
4	1.033	7.378	88.355	1.033	7.378	88.355	1.165	8.320	88.355
5	.836	5.975	94.330						
6	.654	4.671	99.000						
7	.140	.997	99.997						
8	.000	.002	99.999						
9	9.16E-005	.001	100.000						
10	1.67E-005	.000	100.000						
11	7.59E-006	5.42E-005	100.000						
12	2.92E-007	2.09E-006	100.000						
13	4.43E-008	3.16E-007	100.000						
14	1.60E-011	1.14E-010	100.000						

Table 6: Rotated factor loadings matrix. Each loading represents the correlation between the item (i.e. the original variables) and the rotated factors.

Rotated factor loadings

	Factors			
	1	2	3	4
prDM	-.409	.909	-.047	-.035
t090C	.223	-.151	.959	.051
cond	-.306	.321	.885	.007
sbeox0V	.872	-.457	.065	.088
flC	.596	-.164	-.162	.015
seaTurbMtr	-.073	-.009	-.024	.855
xmiss	-.244	.040	-.073	-.617
sbeoxMLL	.939	-.291	-.014	.098
sbeoxMgL	.939	-.291	-.014	.098
sbeox0P	.937	-.293	.061	.099
sal	-.879	.378	-.101	-.071
svCM	-.396	.898	.186	-.026
Density	-.746	.380	-.509	-.074
Depth	-.410	.909	-.047	-.035

Extraction method: Principal Component Analysis
Rotation criterion: Varimax with Kaiser normalisation.

Table 7 - Correlation matrix: all the CTD data have been pooled together.

Correlation matrix

		Pressure	T (°C)	Conductivity [mS/cm]	Oxygen Voltage, SBE 43	Fluorescence, Chelsea Aqua 3 Chl Con [ug/l]	seaTurbMtr OBS, Seapoint Turbidity [FTU]	xmiss: Beam Transmission, Chelsea/ Seatech/ Wetlab CStar [%]	sbeox0ML/L Oxygen, SBE 43 [ml/l], WS = 2	sbeox0Mg/L Oxygen, SBE 43 [mg/l], WS = 2	sbeox0PS Oxygen, SBE 43 [% saturation], WS = 2	sal00 Salinity [PSU]	svCM. Sound Velocity [Chen-Millero, m/s]	sigma-é00. Density [sigma-theta, Kg/m^3]	depSM: Depth [salt water, m], lat = 45
Pressure	r														
	Sig (2-tails)														
	N														
Temperature (°C)	r	-.277**													
	Sig (2-tails)	.000													
	N	28292													
Conductivity [mS/cm]	r	.370**	.739**												
	Sig (2-tails)	.000	.000												
	N	28292	28292												
Oxygen Voltage, SBE 43	r	-.778**	.326**	-.352**											
	Sig (2-tails)	.000	.000	.000											
	N	28292	28292	28292											
Fluorescence, Chelsea Aqua 3 Chl Con [ug/l]	r	-.409**	.059**	-.309**	.522**										
	Sig (2-tails)	.000	.000	.000	.000										
	N	28292	28292	28292	28292										
seaTurbMtr: OBS, Seapoint Turbidity [FTU]	r	.005	.021**	.009	.025**	.021**									
	Sig (2-tails)	.369	.000	.152	.000	.000									
	N	28292	28292	28292	28292	28292									
xmiss: Beam Transmission, Chelsea/Seatech/Wetlab CStar [%]	r	.180**	-.142**	.023**	-.270**	-.120**	-.128**								
	Sig (2-tails)	.000	.000	.000	.000	.000	.000								
	N	28292	28292	28292	28292	28292	28292								
sbeox0ML/L: Oxygen, SBE 43 [ml/l], WS = 2	r	-.650**	.238**	-.393**	.980**	.522**	.031**	-.274**							
	Sig (2-tails)	.000	.000	.000	.000	.000	.000	.000							
	N	28292	28292	28292	28292	28292	28292	28292							
sbeox0Mg/L: Oxygen, SBE 43 [mg/l], WS = 2	r	-.650**	.238**	-.393**	.980**	.522**	.031**	-.274**	1.000**						
	Sig (2-tails)	.000	.000	.000	.000	.000	.000	.000	.000						
	N	28292	28292	28292	28292	28292	28292	28292	28292						
sbeox0PS: Oxygen, SBE 43 [% saturation], WS = 2	r	-.655**	.311**	-.326**	.984**	.514**	.031**	-.279**	.997**	.997**					
	Sig (2-tails)	.000	.000	.000	.000	.000	.000	.000	.000	.000					
	N	28292	28292	28292	28292	28292	28292	28292	28292	28292					
sal00: Salinity [PSU]	r	.700**	-.348**	.334**	-.935**	-.522**	-.032**	.232**	-.928**	-.928**	-.935**				
	Sig (2-tails)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000				
	N	28292	28292	28292	28292	28292	28292	28292	28292	28292	28292				
svCM: Sound Velocity [Chen-Millero, m/s]	r	.972**	-.047**	.572**	-.746**	-.421**	.010	.157**	-.638**	-.638**	-.625**	.664**			
	Sig (2-tails)	.000	.000	.000	.000	.000	.109	.000	.000	.000	.000	.000			
	N	28292	28292	28292	28292	28292	28292	28292	28292	28292	28292	28292			
sigma-é00, Density [sigma-theta, Kg/m^3]	r	.671**	-.715**	-.081**	-.850**	-.417**	-.031**	.237**	-.799**	-.799**	-.837**	.904**	.540**		
	Sig (2-tails)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		
	N	28292	28292	28292	28292	28292	28292	28292	28292	28292	28292	28292	28292		
depSM. Depth [salt water, m], lat = 45	r	1.000**	-.277**	.370**	-.779**	-.409**	.005	.180**	-.650**	-.650**	-.655**	.700**	.972**	.671**	
	Sig (2-tails)	.000	.000	.000	.000	.000	.371	.000	.000	.000	.000	.000	.000	.000	
	N	28292	28292	28292	28292	28292	28292	28292	28292	28292	28292	28292	28292	28292	

** Level of significancy 0.01 (2-tails)

As it can be inferred by looking the factor loadings, the four factors can be explained as follows:

- Factor 1 correlates directly with oxygen and chlorophyll and inversely with Salinity and Density. Therefore Factor 1 is higher for the CTD stations with higher Oxygen and chlorophyll values and lower for stations with a higher salinity;
- Factor 2 correlates directly with pressure, sound velocity and depth;
- Factor 3 correlates directly with temperature and conductivity. It shows also a weak inverse correlation with density;
- Factor 4 correlates directly with turbidity.

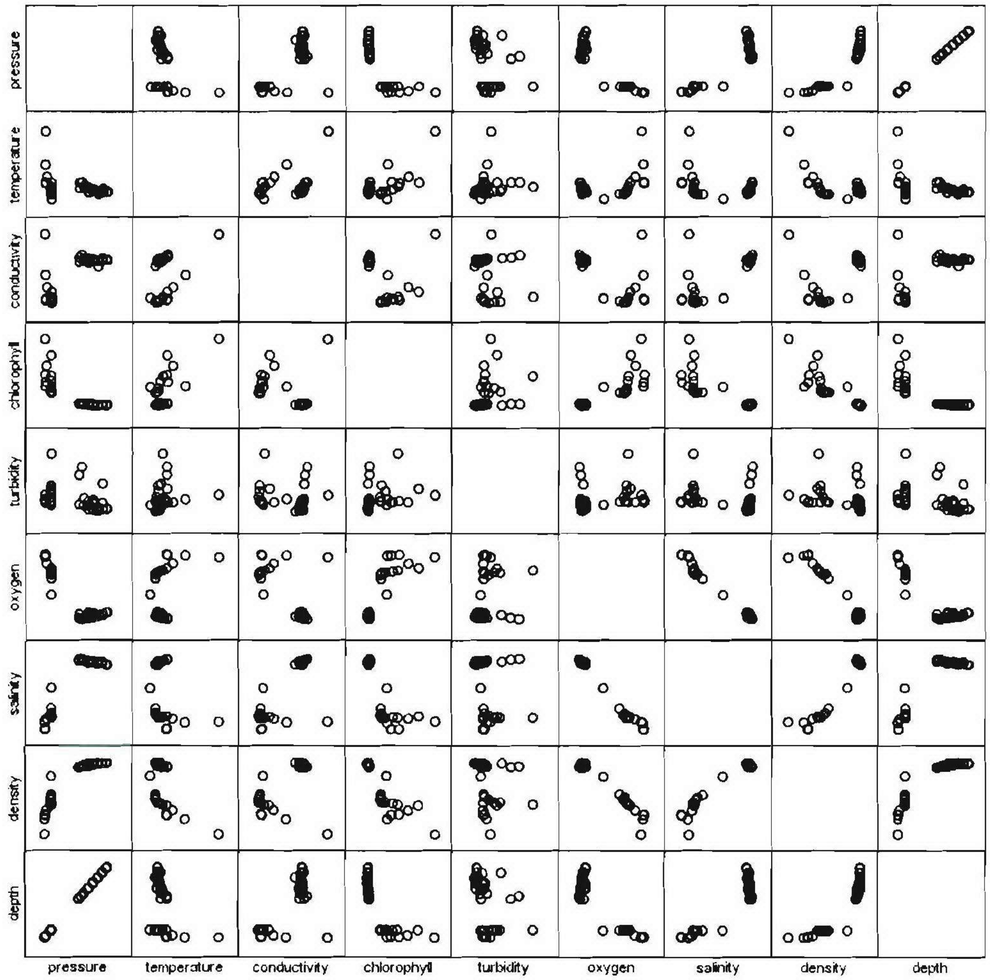


Figure 7: Correlation scatterplot matrix: each square shows the scatterplot for every pair of variables (e.g. the lower square on the left shows the correlation of depth vs pressure).

Consequently the four factors can be easily interpreted in physical terms:

- Factor 1 is the expression of the photosynthetic capability of the upper layers. The higher is the factor the higher is the oxygen productivity, the lower is the factor the denser and saltier and saltier is the water layer.
- Factor 2 is the depth variability.
- Factor 3 is the expression of temperature and conductivity variability.
- Factor 4 is the expression of the variability of turbidity.

These four factors can be used to describe the study area. Figure 8 shows the map related to Factor 1. For every CTD station, the median value of Factor 1 has been plotted. Darker dots represents stations with higher values of Factor 1, vice versa lighter dots are points with lower Factor 1 values.

CTD point values have been also interpolated by using an IDW (i.e. Inverse Distance Weighted)algorithm. The IDW interpolator assumes that each input point has a local influence that diminishes with distance. It weights the points closer to the processing cell greater than those farther away. The graduated color scale is the result of the IDW interpolator. As it can be seen from Fig.8 map the most of the canyon area is characterized by high Factor 1 levels. This means that the most of the water that was sampled in the canyon in the late spring period was highly oxygenated (and therefore with a high degree of photosynthetic production as the high values of cholorophyll can confirm), whereas there are three zones in the area (i.e. the area off the coast of Genoa, the area off the coast of Imperia and the left end of the canyon entrance) where the water was denser, saltier and less oxygenated.

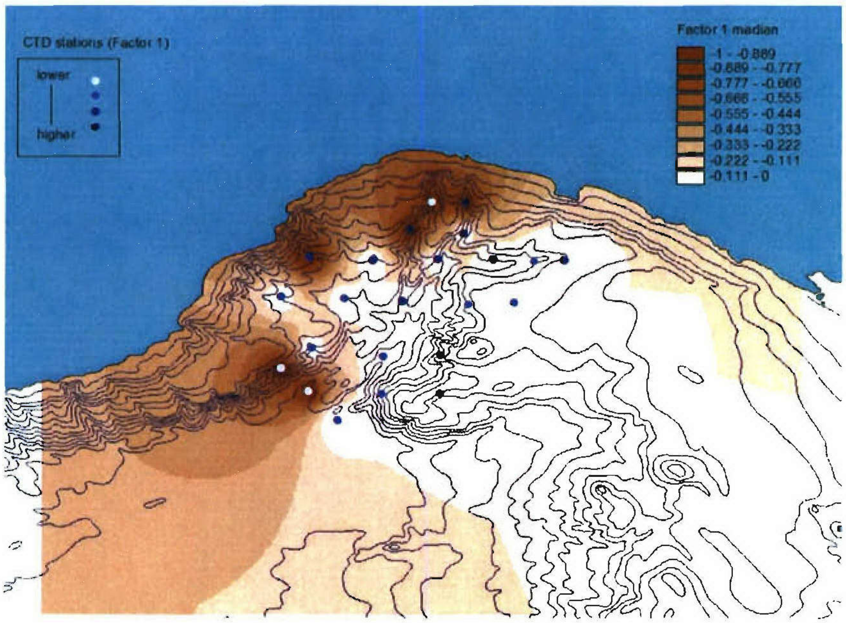


Figure 8: Factor 1 map. The most of the canyon area, as recorded in late spring campaign, was constituted by highly oxygenated and productive waters. Three main area are recognizable from the map where the water was denser, saltier and less oxygenated.
Despite of the fact that Factor 3 accounted for 14% of the total variance, the Factor 3 map, when considering the median values, allows to outline only the outer basin area where the temperature is colder whereas all the canyon area turned out to be much more homogeneous.

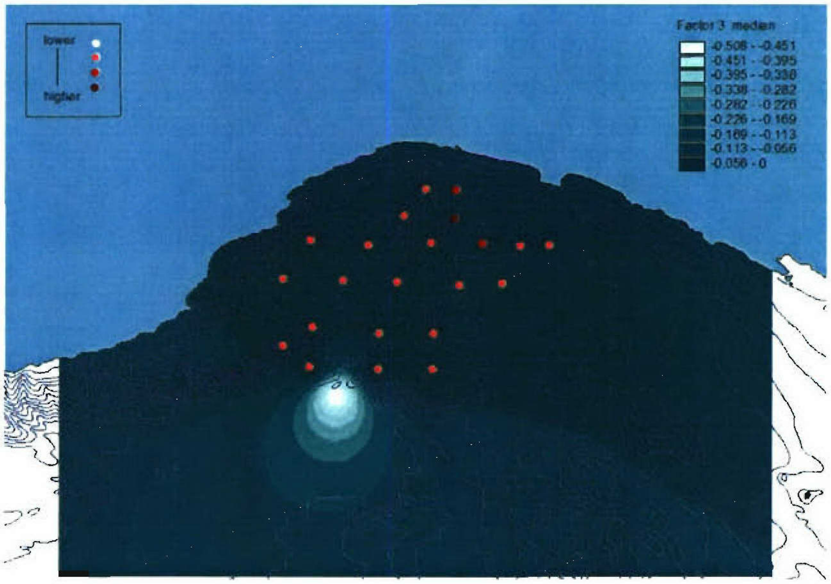


Figure 9: Factor 3 map. The majority of the canyon area, as recorded in late spring campaign, seems to be quite homogenous in terms of temperature profiles. The outer basin area seems to be characterised by waters colder than inside the canyon.

When considering Factor 3 extreme values (i.e. minimum and maximum) other patterns are recognizable. The area off the coast of La Spezia seems to be much warmer than the rest of the canyon area (see Fig. 9). Considering the Factor 3 extreme values, the North-Eastern part of the canyon area is characterized by the warmest temperatures and the higher conductivity values whereas the South-Western area is characterized by the coldest temperatures and the lower conductivity values (Fig.10).

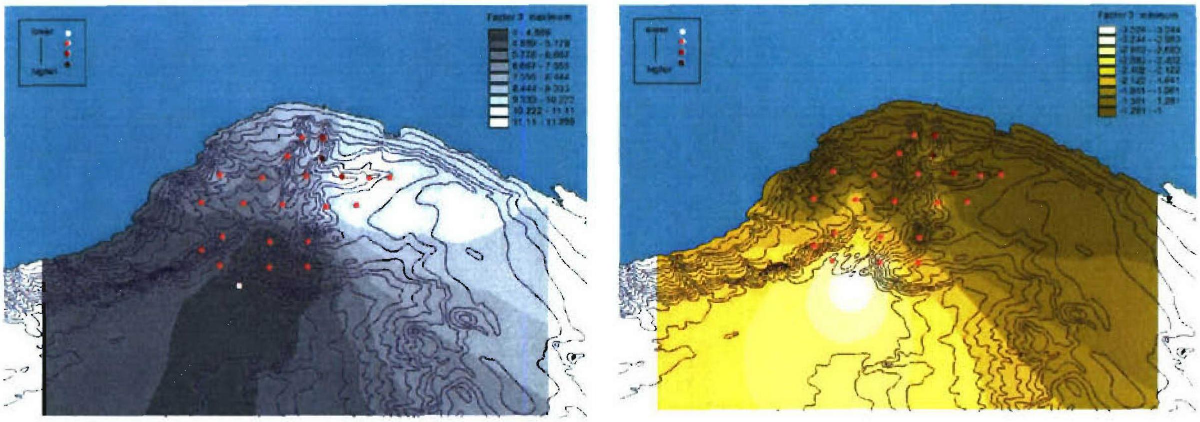


Figure 10: Factor 3 maps: the maximum (left) and the minimum (right) values area shown. The North-Eastern part of the canyon area is characterised by the warmest temperatures and the higher conductivity values whereas the South-Western area is characterized by the coldest temperatures and the lower conductivity values.

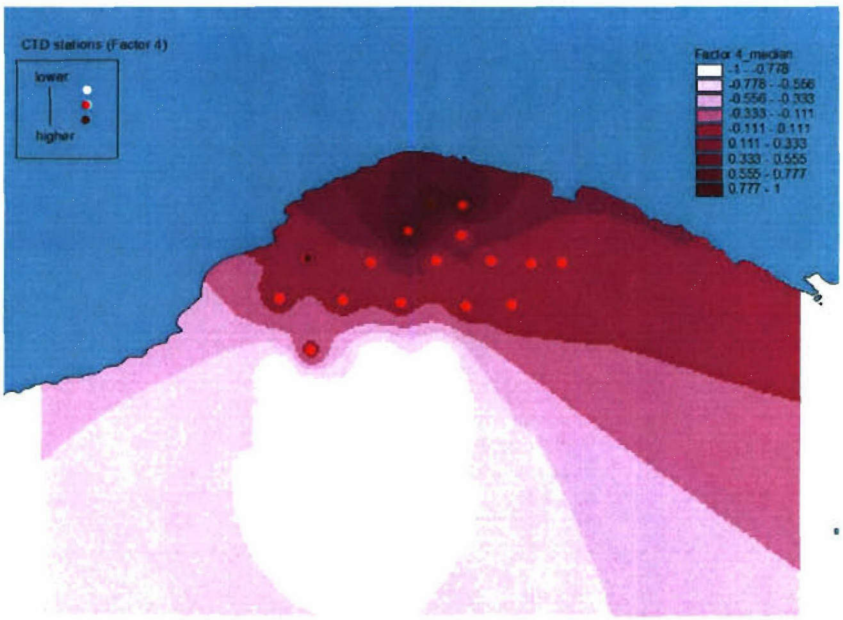


Figure 11: Factor 4 map. The canyon area seems characterized by three different turbidity patterns structured on a North-to-South axis: the upper northern area with higher values, the intermediate, and the southern area with the lowest values.

It is well known that submarine canyons act as traps for suspended particulate matter (SPM). Looking at the Factor 4 map (Fig.11) it is possible to see higher turbidity values in the northern area of the canyon, values that gradually decrease moving from North to South within the canyon.

Cluster Analysis

The same Factors described in the previous paragraph were used to run a Cluster Analysis (CA) in order to obtain a multivariate zonation of the canyon area. A Hierarchical Cluster Analysis was then performed by using the Euclidean Distance as measure of similarity and Ward's method as linkage criterion. CA was applied on the 6 Factors descriptive statistics (mean, median, minimum, maximum and standard deviation) of the 36 CTD stations. The dendrogram shown in Fig.12 summarizes the CA results.

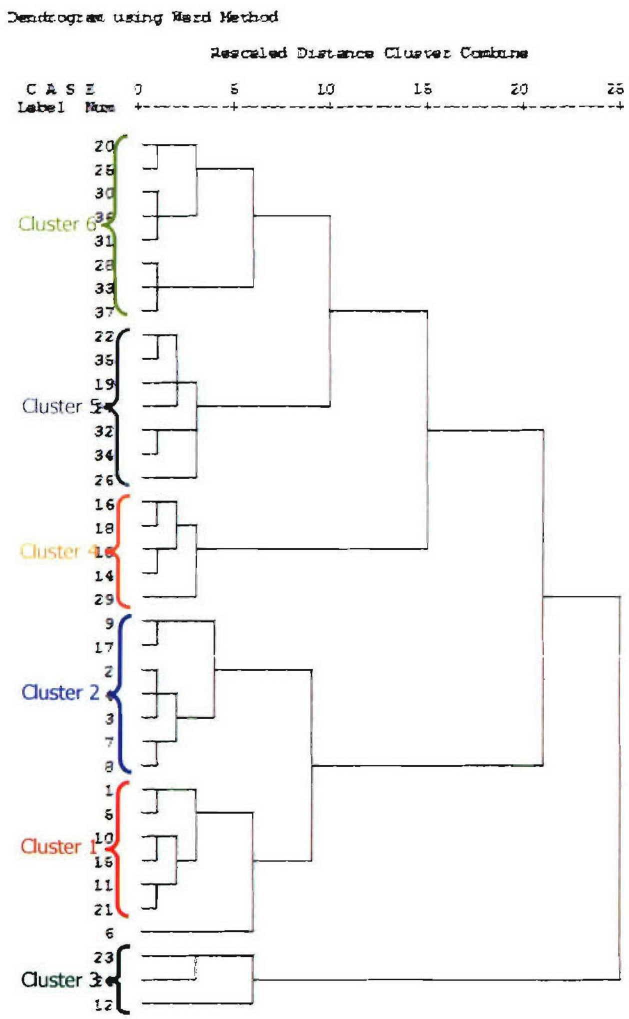


Figure 12: Dendrogram showing the hierarchy of the CTD stations' similarity. At least six clusters are recognizable.

The bar charts shown in Fig.13 summarize the Factor statistics that characterize each cluster. An example will clarify the meaning of these charts. Consider Factor 1 chart and the first two clusters: they have more or less the same statistics in terms of mean, median, maximum and standard deviation whereas cluster 1 has a much lower minimum than cluster 2. On the other hand, looking again at the same

chart: cluster 4 and 5 share approximately the same statistics apart from the standard deviation (i.d. FACTOR_sd) which is higher for cluster 4 and the minimum (i.d. FACTOR_min) which much lower in cluster 4. Cluster 4 and 5 have also the highest mean and median values among all the other clusters. To facilitate understanding what the 6 clusters represent in terms of original variables, Table 5 reports the statistics of the clusters in term of the original variables instead of the factors.

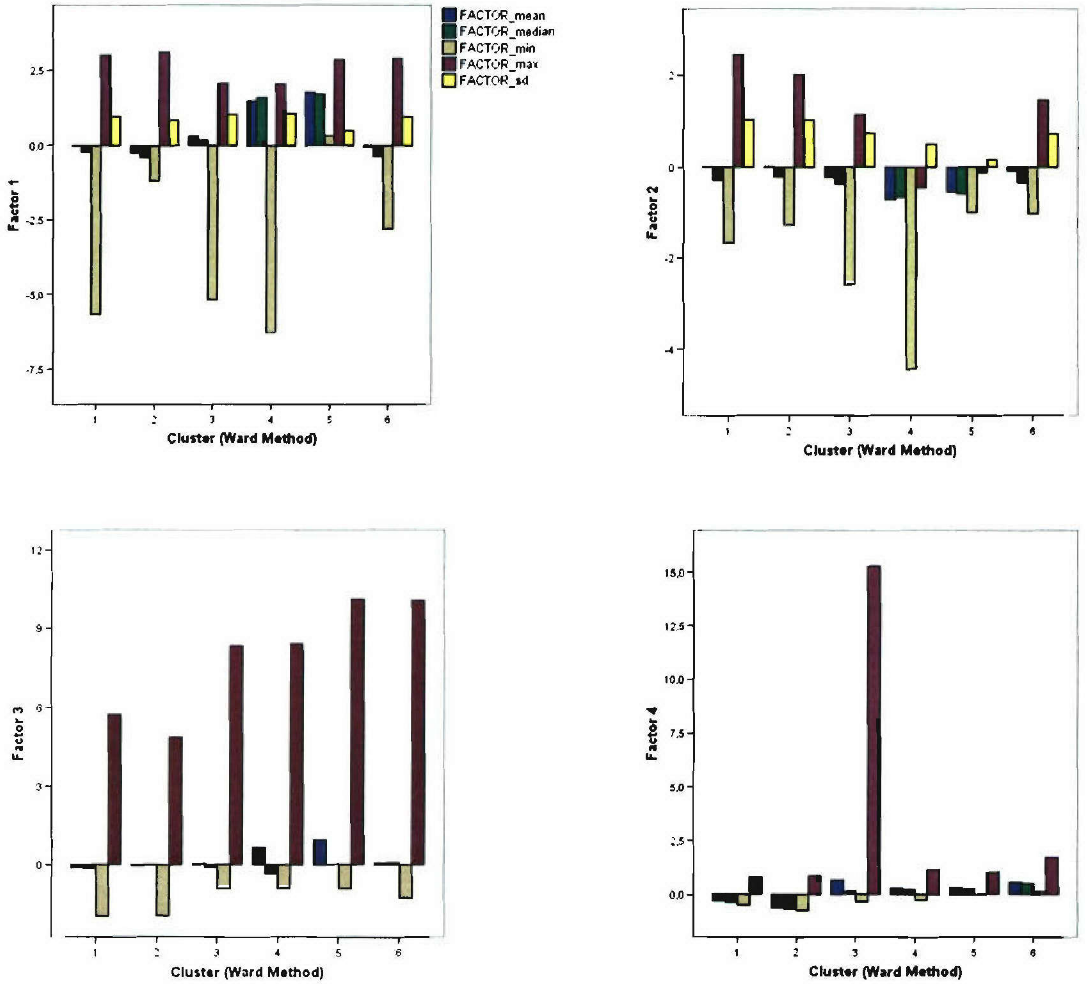


Figure 13: Bar charts summarizing the Factor statistics that characterize each cluster. An example will clarify the meaning of these charts: considering Factor 1 chart and the first two clusters: they have more or less the same statistics in terms of mean, median, maximum and standard deviation whereas cluster 1 has a much lower minimum than cluster 2.

Even though a clear zonation is not easily recognizable plotting the clusters on the map (Fig. 15), a kind of a pattern seems to be recognizable. The combined presence of less productive, denser and

saltier water (cluster 6) together with highly productive, less dense and oxygenated waters on the north-eastern upper portion of the canyon area and the presence of denser, colder, less productive and oxygenated waters (clusters 1 and 2) on the southwestern mouth of the canyon which is much more similar to the open basin.

Table 8 - Statistics of the six clusters

Cluster Characteristics

cluster		temperature	conductivity	fluorescence	turbidity	% saturation dissolved oxygen	salinity	density
1	Mean	13.40	45.37	.02	.05	76.12	38.51	29.06
	Std. Deviation	.08	.27	.01	.02	4.27	.08	.05
	Minimum	13.24	44.76	.01	.03	73.09	38.34	28.96
	Maximum	13.47	45.51	.04	.07	85.55	38.55	29.09
	Median	13.42	45.48	.01	.05	74.73	38.54	29.08
2	Mean	13.42	45.47	.01	04	74.15	38.55	29.08
	Std. Deviation	.03	02	.00	.01	.99	.01	.01
	Minimum	13.39	45.43	.01	.03	73.04	38.53	29.07
	Maximum	13.48	45.50	01	.05	76.11	38.55	29.08
	Median	13.40	45.48	.01	.03	73.88	38.55	29.08
3	Mean	13.48	45.25	.03	.09	82.11	38.40	28.95
	Std. Deviation	.04	.45	02	.04	14.18	26	21
	Minimum	13.46	44.73	.01	06	73.22	38.10	28.70
	Maximum	13.53	45.52	.05	.14	98.46	38.56	29.08
	Median	13.47	45.51	.01	.08	74.67	38.55	29.05
4	Mean	13.52	44.77	.05	.12	100.54	38.08	28.67
	Std Deviation	.15	12	.02	.08	4.28	.04	.06
	Minimum	13.37	44.67	03	.06	96.45	38.01	28.59
	Maximum	13.72	44.96	.08	.26	107.03	38.12	28.74
	Median	13.51	44.74	.05	.09	98.89	38.10	28.69
5	Mean	13.72	44.98	.06	.09	101.34	38.09	28.64
	Std. Deviation	49	.47	.04	.02	5.32	.06	.13
	Minimum	13.35	44.68	03	.07	94.30	38.00	28.41
	Maximum	14.71	45.97	.12	.12	107.40	38.17	28.79
	Median	13.59	44.72	.04	08	99.99	38.10	28.68
6	Mean	13.48	45.49	.01	.09	74.98	38.55	29.06
	Std. Deviation	08	.05	.00	06	1.36	01	.01
	Minimum	13.39	45.45	.01	.05	72.53	38.54	29.05
	Maximum	13.61	45.58	.01	.21	76.28	38.57	29.08
	Median	13.46	45.48	.01	.06	75.57	38.55	29.06

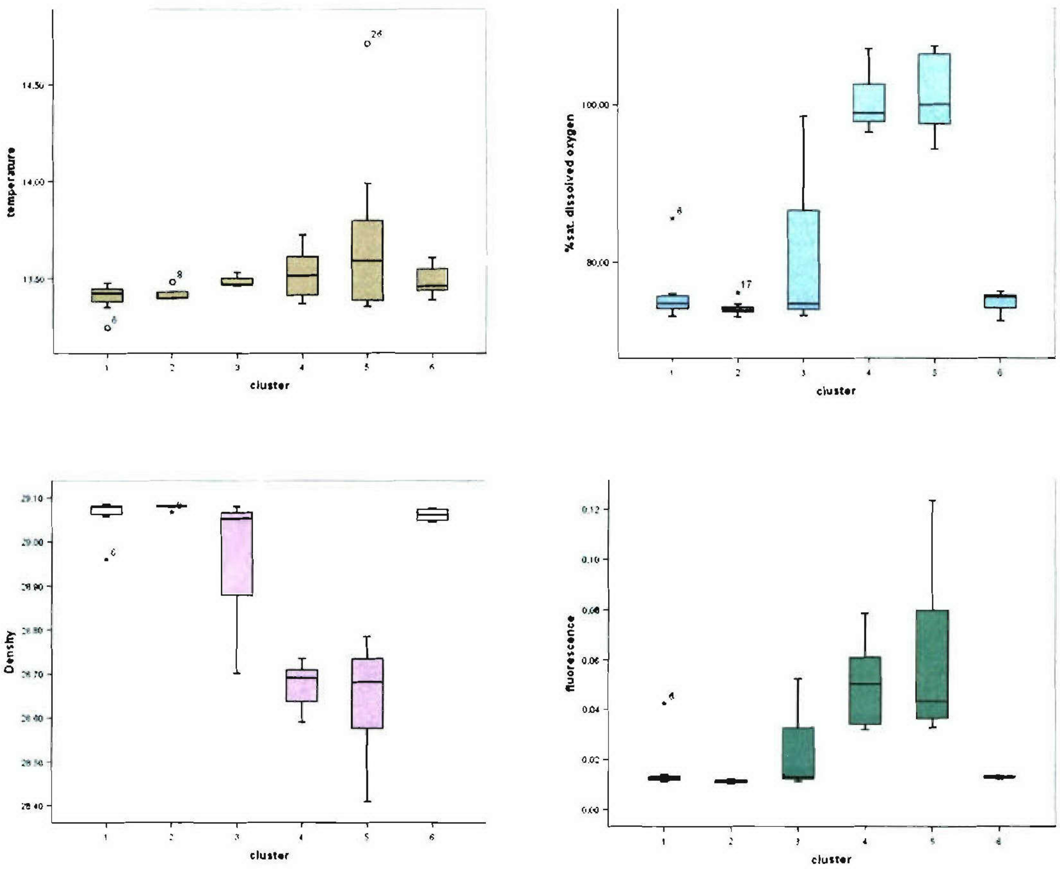
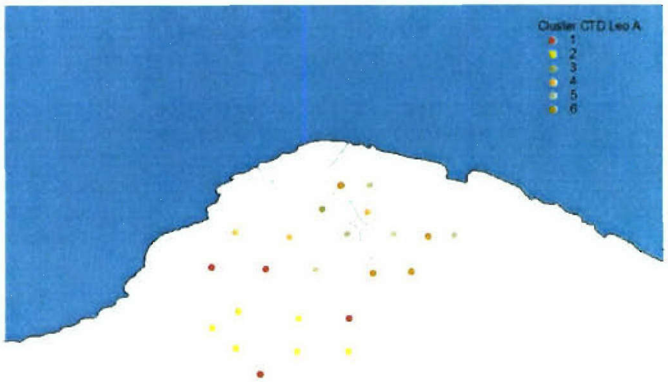


Figure 14: Boxplots summarizing the variables that better differentiate the six clusters. Boxplots show the median (ie the bold black line that lies within the box), the 25° and 74° percentiles (ie the upper end lower end of the box) and the outliers.



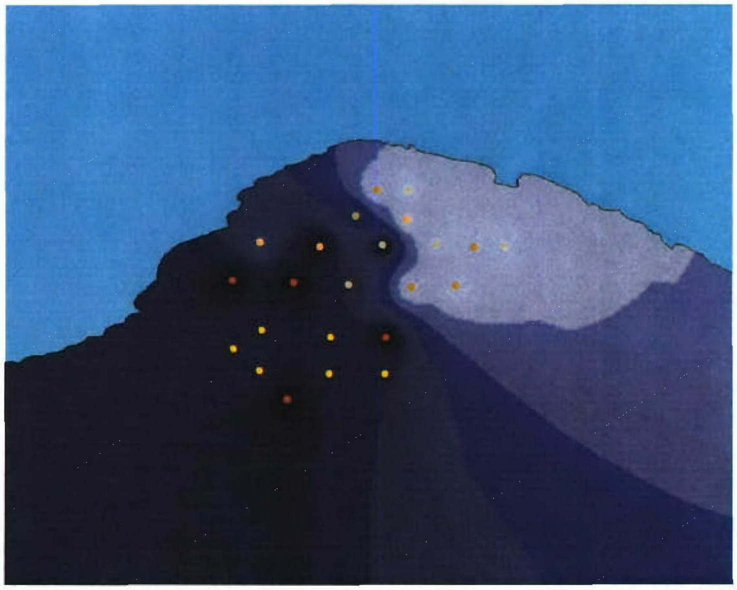


Fig.15: Even though a clear zonation is not easily recognizable plotting the clusters on the map a kind of a pattern seems to be recognizable. The combined presence of less productive, denser and saltier water together with highly productive, less dense and oxygenated waters on the north-eastern upper portion of the canyon area and the presence of denser, colder, less productive and oxygenated waters on the southwestern mouth of the canyon which is much more similar to the open basin.

1.7. Ziphius B campaign (4 Sep - 11 Sep 03)

Factor Analysis

Following the same methodology applied for Ziphius A data campaign, a factor analysis was applied also to the Ziphius B data as first

step for the analysis. Factor Analysis was based on standardized data via a previous correlation analysis obtained by pooling all the CTD data together (see Table 9). The VARIMAX rotation allowed rotation of the principal component axes. These resulting factors maintained their orthogonality (i.e. being uncorrelated) to each other. Factor Analysis results are shown in Table 10. Four factors were retained on the basis of the "eigenvalue higher than 1" criterion.

Table 9: Initial Eigenvalues, variance explained, and cumulative variance explained for the principal component and the factor analysis solution.

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.420	52.999	52.999	7.420	52.999	52.999	5.337	38.122	38.122
2	2.765	19.753	72.752	2.765	19.753	72.752	3.485	24.890	63.013
3	1.651	11.795	84.547	1.651	11.795	84.547	2.609	18.635	81.648
4	1.072	7.659	92.206	1.072	7.659	92.206	1.478	10.558	92.206
5	.565	4.037	96.243						
6	.448	3.199	99.442						
7	.077	.547	99.989						
8	.001	.009	99.999						
9	.000	.001	99.999						
10	7.29E-005	.001	100.000						
11	2.76E-006	1.97E-005	100.000						
12	1.48E-007	1.05E-006	100.000						
13	3.48E-008	2.49E-007	100.000						
14	2.11E-011	1.51E-010	100.000						

Extraction Method: Principal Component Analysis.

The factors were interpreted on the basis of the factor loadings (Table 10).

Table 10: Rotated factor loadings matrix. Each loading represents the correlation between the item (i.e. the original variables) and the rotated factors.

Rotated Component Matrix[a]

	Component			
	1	2	3	4
prDM	-.381	-.213	.892	118
t090C	.246	.963	-.084	-.053
cond	116	.989	.028	-.044
sbeox0V	.854	.364	-.349	-.033
flC	.738	-.068	-.250	-.065
seaTurbMtr	.004	.020	-.089	-.848
xmiss	-.019	-.057	.068	.845
sbeoxMLL	.966	.138	-.156	.011
sbeoxMgL2	.966	138	-.156	.011
sbeox0P	.905	.375	-.153	-.003
sal	-.886	-.282	.276	.013
svCM	-.185	.564	.800	.068
Density	-.441	-.878	160	.046
Depth	-.381	-.214	.891	.117

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 5 iterations.

As it can be inferred by looking the factor loadings, the four factors are quite similar to the factors extracted for the Ziphius A data and can be explained as follows:

- Factor 1 correlates directly with oxygen and chlorophyll and inversely with salinity. Therefore Factor 1 is higher for the CTD stations with higher Oxygen and chlorophyll values and lower for stations with a higher salinity.
- Factor 2 correlates directly with temperature and conductivity and inversely with density. It shows also a weak direct correlation with sound velocity;
- Factor 3 correlates directly with pressure, sound velocity and depth;
- Factor 4 correlates directly with turbidity.

However even though there are obvious similarities in the data pattern, some differences with the Ziphius A campaign should be also mentioned:

- in contrast with Ziphius A campaign, it should be observed that the Ziphius B Factor1 does not strongly correlate with density;
- Factor 2 and 3 hierarchy seems to be inverted with respect to the Ziphius A factor extraction since temperature, conductivity and density showed, in the late summer campaign, a higher variability than pressure and sound velocity.
- Density shows much higher correlations with temperature and conductivity than during the late spring campaign (see Table 11).

These four factors can be used to describe the study area. Figure 17 shows the map related to Factor 1. For every CTD station, the median value of Factor 1 has been plotted. Darker dots represent stations with higher values of Factor 1, vice versa lighter dots are points with lower Factor 1 values.

CTD point values have been also interpolated by using an IDW (i.e. Inverse Distance Weighted) algorithm.

As it can be seen from the Fig. 17 map, even though the most of the canyon area was still characterized by high Factor 1 levels as recorded also during the Ziphios A campaign, the late summer picture appears to be much more heterogeneous. The less oxygenated and saltier zones are still visible too but it seems that there are more than three of them. Also the situation with temperature and conductivity during the late summer campaign seems to be much more heterogeneous. It's interesting to observe that the canyon mouth (i.e. the area closer to the open basin) seems to be characterized by waters warmer than near the coast. As Fig. 19 clearly shows, the turbidity pattern is the only parameter that seems to be the same observed also in the late spring campaign, even though the three turbidity areas now seem to be orientated on a East-to-West axis.

Table 11 - Ziphius B campaign: correlation matrix: all the CTD data have been pooled together.

Correlations

		pressure	temperature	conductivity	fluorescence	turbidity	%sat. dissolved oxygen	salinity	sound velocity	density	depth
pressure	Pearson Correlation										
	Sig. (2-tailed)										
	N										
temperature	Pearson Correlation	-.380**									
	Sig. (2-tailed)	.000									
	N	22932									
conductivity	Pearson Correlation	-.235**	.984**								
	Sig. (2-tailed)	.000	.000								
	N	22932	22932								
fluorescence	Pearson Correlation	-.488**	.171**	.051**							
	Sig. (2-tailed)	.000	.000	.000							
	N	22932	22932	22932							
turbidity	Pearson Correlation	-.183**	.076**	.059**	.091**						
	Sig. (2-tailed)	.000	.000	.000	.000						
	N	22932	22932	22932	22932						
%sat. dissolved oxygen	Pearson Correlation	-.564**	.591**	.467**	.607**	.027**					
	Sig. (2-tailed)	.000	.000	.000	.000	.000					
	N	22932	22932	22932	22932	22932					
salinity	Pearson Correlation	.642**	-.510**	-.364**	-.699**	-.043**	-.937**				
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000				
	N	22932	22932	22932	22932	22932	22932				
sound velocity	Pearson Correlation	.672**	.429**	.559**	-.351**	-.113**	-.084**	.228**			
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000			
	N	22932	22932	22932	22932	22932	22932	22932			
density	Pearson Correlation	.502**	-.972**	-.918**	-.339**	-.074**	-.744**	.698**	-.284**		
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000		
	N	22932	22932	22932	22932	22932	22932	22932	22932		
depth	Pearson Correlation	1.000**	-.380**	-.236**	-.489**	-.183**	-.565**	.642**	.672**	.502**	
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	
	N	22932	22932	22932	22932	22932	22932	22932	22932	22932	

** Correlation is significant at the 0.01 level (2-tailed).

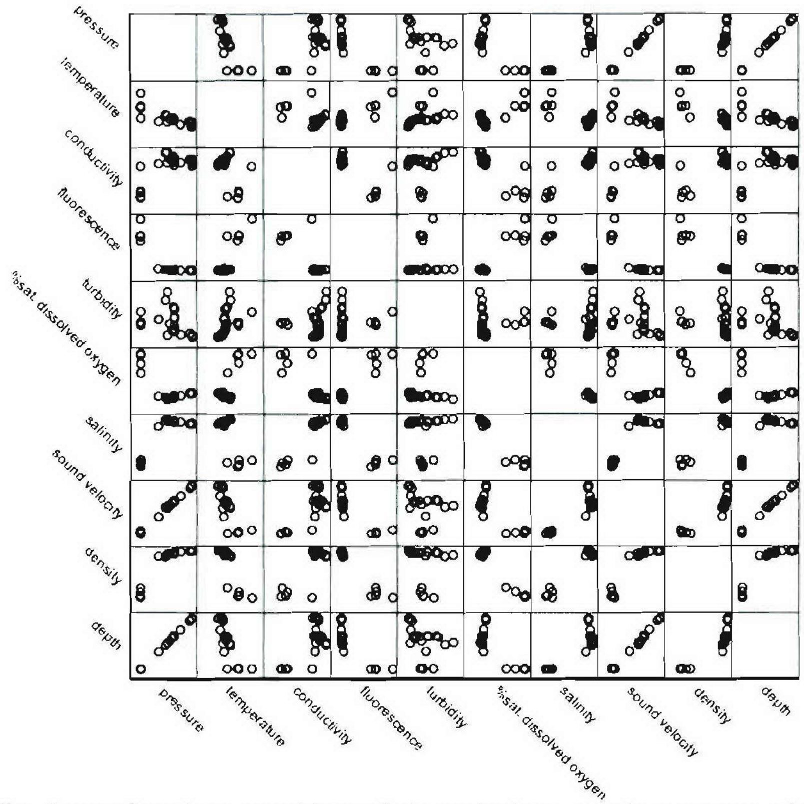


Figure 16: Correlation scatterplot matrix: each square shows the scatterplot for every couple of variables (e.g. the lower square on the left shows the correlation of depth vs pressure).

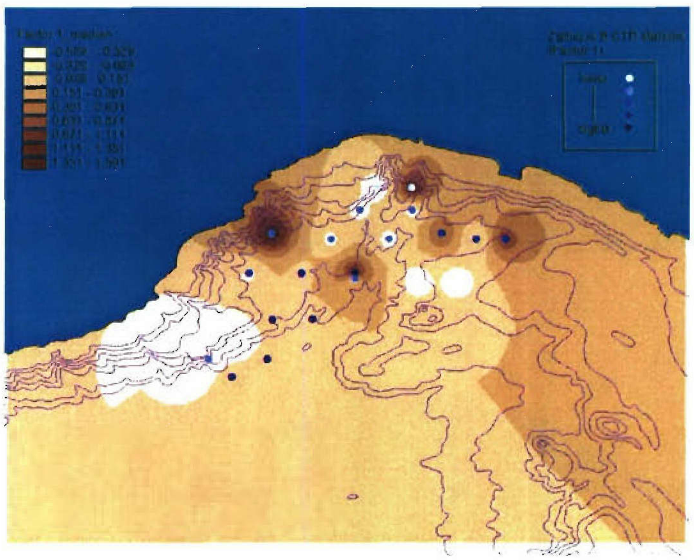


Figure 17: Factor 1 map. In contrast with what was the situation in the late spring campaign, there is much more heterogeneity, even though most of the canyon area is still constituted by highly oxygenated and productive waters. Several spot are also recognizable from the map where the water is denser, saltier and less oxygenated.

Figure 18: Factor 2 map. In contrast with what was the situation in the late spring campaign, there is much more heterogeneity. On the map it is also recognizable the presence of colder water that surprisingly is much closer to the coast than to the open basin.

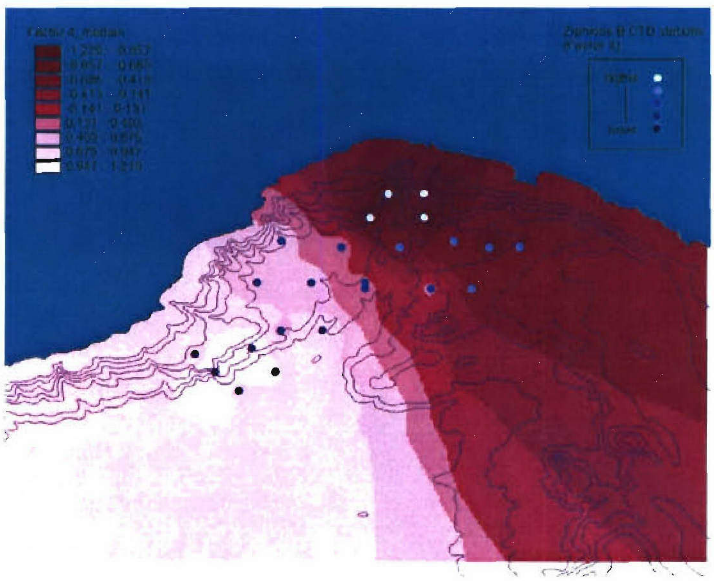


Figure 19: Factor 4 map. The canyon area seems characterised by three different turbidity patterns that seem to be orientated on a East-to-West axis.

Cluster Analysis

As it was done for the Ziphios A campaign, the same Factors described in the previous paragraph were used to run a Cluster Analysis (CA) in order to obtain a multivariate zonation of the canyon area. A Hierarchical Cluster Analysis was then performed by using the Euclidean Distance as measure of similarity and Ward's method as linkage criterion. CA was applied on the 6 Factors descriptive statistics (mean, median, minimum,

maximum and standard deviation) of the 27 CTD stations. The dendrogram shown in Fig.20 summarizes the CA results.

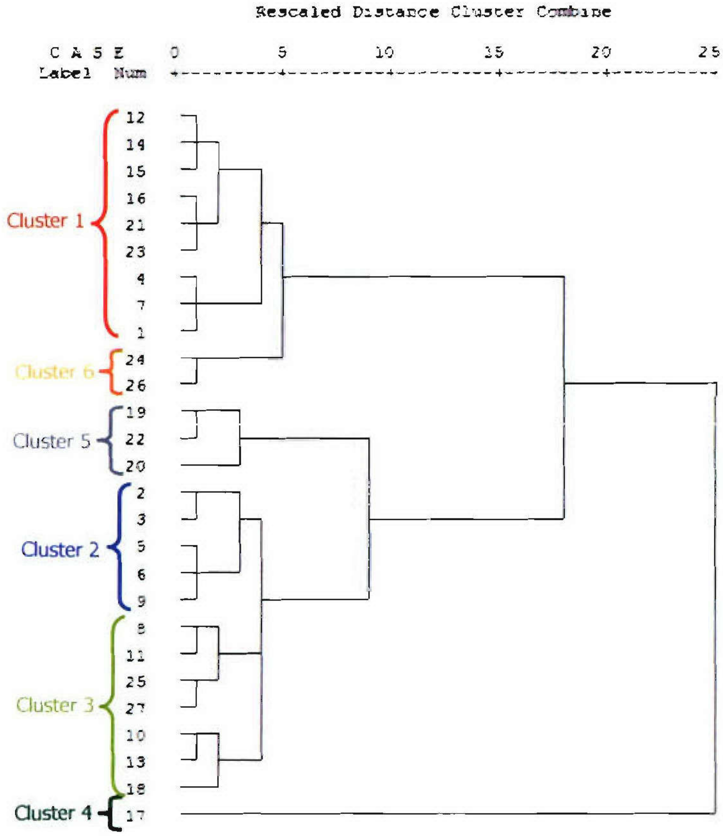


Figure 20: Dendrogram showing the hierarchy of the CTD stations' similarity. At least six clusters are recognizable however the greater varaibility present in this late summer campaign is also recognizable by the fact that three out of six clusters include a maximum of 3 stations.

Just looking at the dendrogram it is immediately obvious that the environmental context of the late summer campaign is quite different that in late spring. In late summer there are three clusters constituted by a maximum of 3 stations. The bar charts shown in Fig. 21 summarize the Factor statistics that characterize each cluster. To facilitate understanding what the 6 clusters represent in terms of original variables, Table 12 reports the statistics of the clusters in term of the original variables instead of the factors.

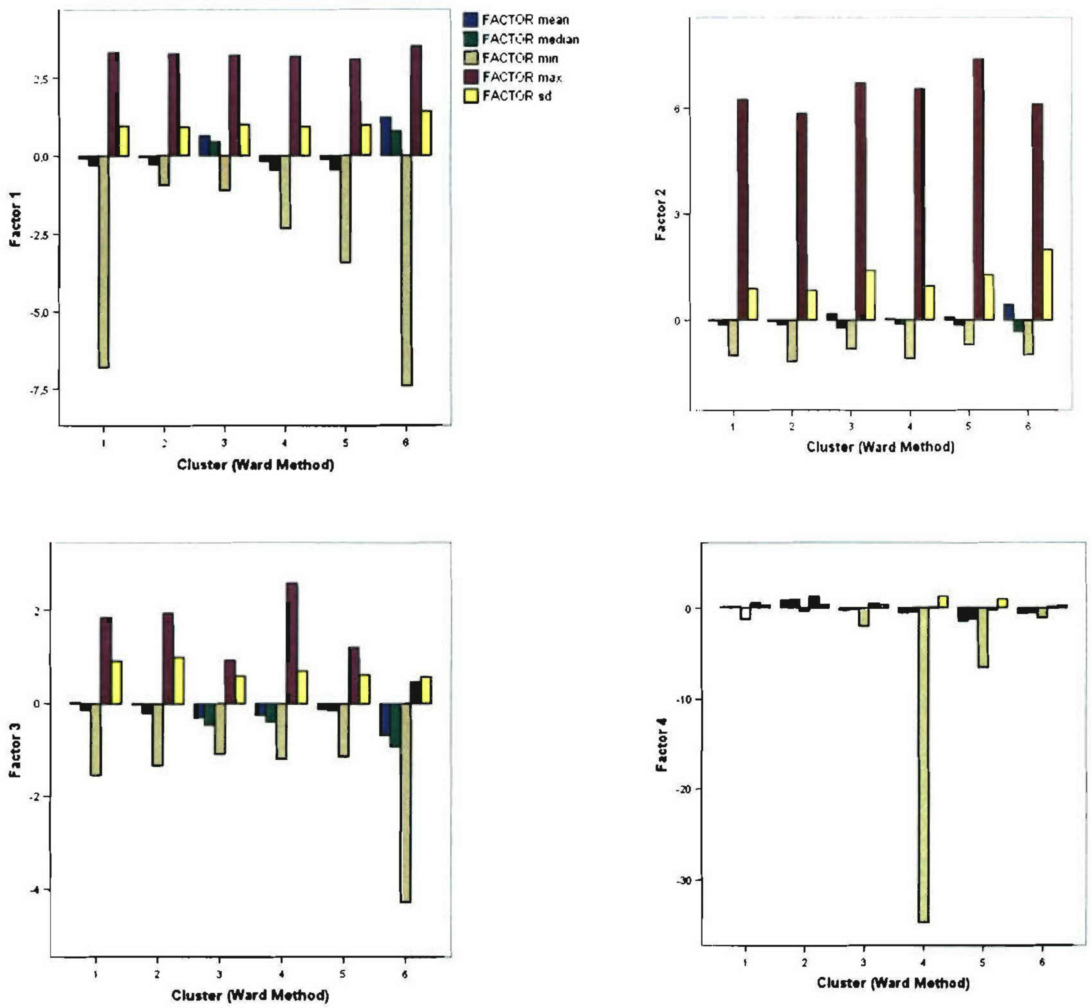


Figure 21: Bar charts summarizing the Factor statistics that characterize each cluster. As seen for the late spring campaign, each graph shows the complete set of statistics (mean, median, min, max and standard deviation) Factor by Factor. So, for example looking at the Factor 4 chart: all the clusters are more or less homogeneous in terms of mean, median, maximum and standard deviation whereas they differ a lot in terms of Factor minimum.

Even though a clear zonation is even more difficult to recognize than it was for the late spring campaign (Fig. 22), a kind of a pattern is still recognizable. The colder and less productive area close the canyon mouth towards the open basin (clusters 1 and 2) and the presence of a mixing area (cluster 3, characterized by the higher variability) where the Tyrrhenian sea waters mix with the open basin waters and the waters rich of suspended particulate matter (SPM) that are typical of the northernmost canyon area (cluster 5).

Table 12 - Statistics of the six clusters

Cluster characteristics

Cluster (Ward Method)		temperature	conductivity	fluorescence	turbidity	% saturation. dissolved oxygen	salinity	density
1	Mean	13.50	45.49	.01	.04	78.99	38.56	29.08
	Std. Deviation	.06	.03	.00	.02	.77	.01	.01
	Median	13.53	45.49	.01	.04	78.78	38.56	29.07
	Minimum	13.40	45.43	.01	.02	78.08	38.54	29.07
	Maximum	13.58	45.54	.01	.09	80.33	38.57	29.09
2	Mean	13.48	45.48	.01	.03	79.52	38.54	29.08
	Std. Deviation	.04	.02	.00	.02	.98	.02	.02
	Median	13.50	45.47	.01	.03	80.14	38.54	29.09
	Minimum	13.41	45.46	.01	.02	78.11	38.52	29.04
	Maximum	13.52	45.50	.01	.06	80.33	38.56	29.09
3	Mean	13.68	45.37	.03	.06	87.17	38.39	28.89
	Std. Deviation	.20	.19	.02	.02	10.52	.21	.22
	Median	13.55	45.44	.01	.06	79.23	38.55	29.06
	Minimum	13.53	45.07	.01	.04	78.44	38.14	28.65
	Maximum	14.04	45.52	.06	.09	98.65	38.56	29.08
4	Mean	13.56	45.51	.01	.05	78.09	38.57	29.07
	Std. Deviation							
	Median	13.56	45.51	.01	.05	78.09	38.57	29.07
	Minimum	13.56	45.51	.01	.05	78.09	38.57	29.07
	Maximum	13.56	45.51	.01	.05	78.09	38.57	29.07
5	Mean	13.61	45.56	.01	.10	77.95	38.58	29.05
	Std. Deviation	.04	.03	.00	.02	.61	.01	.02
	Median	13.62	45.58	.01	.10	78.14	38.58	29.05
	Minimum	13.56	45.53	.01	.08	77.26	38.57	29.04
	Maximum	13.64	45.59	.01	.12	78.44	38.58	29.08
6	Mean	13.68	45.12	.04	.05	91.86	38.19	28.72
	Std. Deviation	15	.04	.00	.00	3.18	.02	.03
	Median	13.68	45.12	.04	.05	91.86	38.19	28.72
	Minimum	13.57	45.09	.04	.05	89.61	38.18	28.70
	Maximum	13.79	45.15	.04	.05	94.11	38.20	28.74

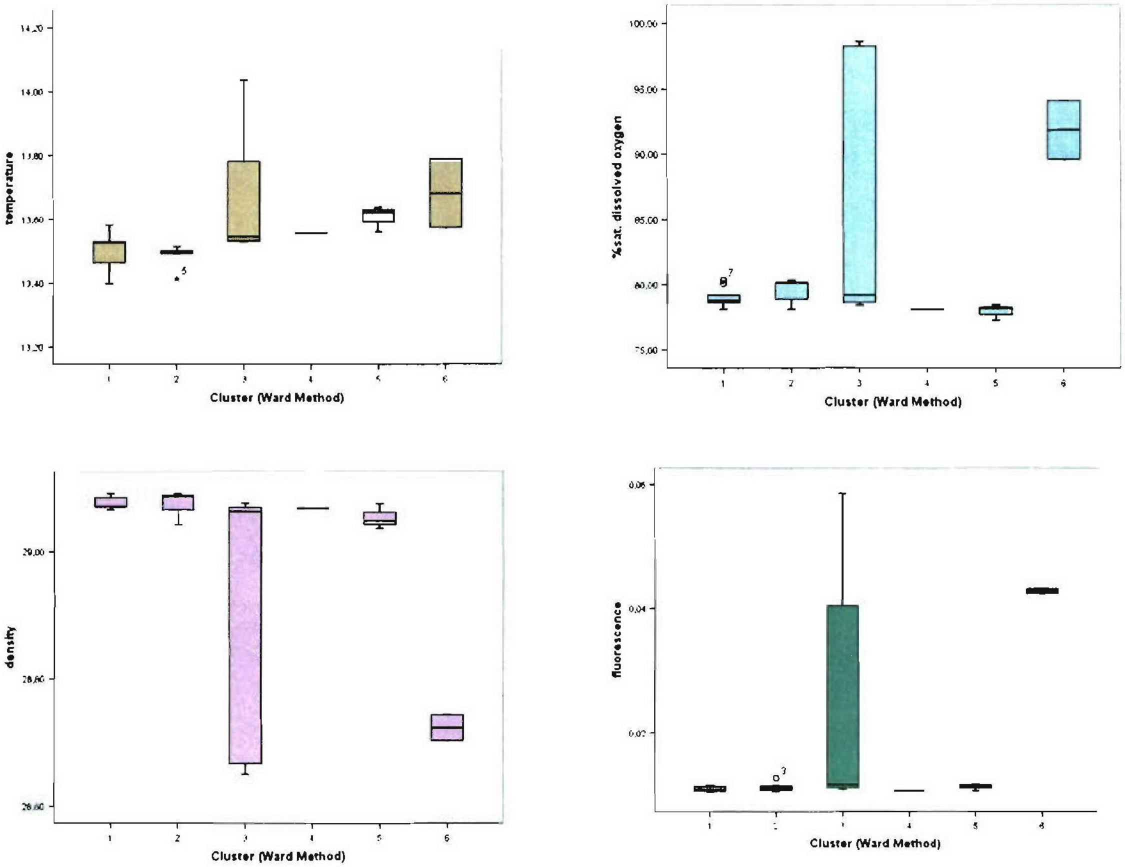


Figure 22: Boxplots summarizing the variables that better differentiate the six clusters. Boxplots show the median (i.e. the bold black line that lies within the box), the 25° and 74° percentiles (i.e. the upper end lower end of the box) and the outliers.

Figure 23: Even though a clear zonation is even less visible than it was for the late spring campaign, a kind of a pattern is still recognizable: the colder and less productive area close the canyon mouth towards the open basin (clusters 1 and 2) and the presence of a mixing area (cluster 3, characterized by the higher variability) where the Tyrrhenian sea waters mix with the open basin waters and the waters rich of suspended particulate matter (SPM) that are typical of the northernmost canyon area (cluster 5).

CONCLUSIONS:

The Genoa canyon is a place where different waters mix together: the open basin water masses that are driven towards to coast, the saltier and less productive waters coming from the Thyrrenian sea and the waters rich of suspended particulate that give the turbidity effect that can be observed at the stations at the northern edge of the canyon.

In the 2002 summer campaign (Sirena 2002: 15-23 July), both oceanographic measurements and ziphius sighting observations were taken at 21 stations in the canyon region within an area of about 10,600 km^2. Sirena 2002 data set allowed to correlate the beaked whale presence to the habitat features derived from the measurements. A model was developed to analyze Cuvier's beaked whale presence/absence data. Model results outlined a lack of correlation with most of the near surface oceanographic features

and suggested that beaked whale presence was highly correlated with environmental conditions related to the mesopelagic zone.

This work was aimed to investigate more deeply the oceanographic peculiarity of the canyon area by using the data collected in 2003 during two additional sea trials (Ziphius campaigns) which have been focused specifically on the canyon area and that were respectively conducted in a late-spring and early-fall period.

This analysis showed that the canyon is affected by a significant degree of seasonal variability even though the features that were described for the 2002 summer campaign are still recognizable. However the patterns are slightly different. Unfortunately for 2003 no ziphius sighting data were available to overlay their distribution with the oceaonographic patterns that were outlined in the summer campaign. Notwithstanding, since we know from that summer campaign that the ziphius like the most the areas where the water mixing produces the most interesting patterns, it is reasonable to suspect that the ziphius distribution might be driven by the seasonal variability of the canyon environmental context.

SIGNIFICANCE:

This work results clearly shows that the Genoa canyon area is characterized by a typical mixing pattern, that can be recognized independently from the season, and also seasonality features.
Since previous research have demonstrated that ziphius distribution within the canyon is definitely not correlated to any parameter above the thermocline, but strongly linked to areas where the water column profile below thermocline are peculiar and heterogeneous with respect to the surrounding context, it is quite reasonable to suspect that ziphius distribution might be affect by the seasonality observed. More dedicated campaigns, carried also in periods different from summer, are needed to collect enough data to increase further our knowledge about ziphius distribution in the canyon. Such data will eventually be used to develop habitat use models that enable to account also for seasonality.

PATENT INFORMATION: N/A

REFERENCES:

Some results of previous analysis done for the canyon has been reported at some ECS and MMS International conferences and included either in the corresponding Proceeding or in the Book of Abstracts:

Azzellino, A., D'Amico, A., McGehee, D., and Portunato, N. 2001. "A preliminary investigation on cetacean habitat in the Ligurian Sanctuary. (Sirena'99)." In: European Research on Cetaceans -15. Proc. 15th Ann. Conf. ECS, Rome, Italy, 6-10 May, 2001. (Eds. P.G.H. Evans, R. Pitt-Aiken, and F. Borsani): 244-248.

Azzellino, A., Borsani, J.F., D'Amico, A., Demer, D., McGehee, D., Portunato, N., Teloni, V. 2001. "A G.I.S. integrated database to investigate cetacean distribution in the Ligurian sanctuary. (sirena'99 and '00 operations)." in Abstracts of the 14th Biennial Conference on the Biology of Marine Mammals, Vancouver, Canada. 28/11-3/12, 2001.

Azzellino, A., Carron, M., D'Amico, A., Misic, C., Podestà, M., Portunato, N., Stoner, R. 2003. "Cuvier's beaked whale (Ziphius cavirostris) habitat use and distribution in the Genoa canyon area

(Sirena'02)". In: European Research on Cetaceans -17 presented at the 17th annual European Cetacean Society Conference in March, 2003.

Also the canyon habitat analysis was presented and included in the book of abstract of the ECOUS Symposium, 12-16 May 2003 San Antonio, TX.